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BAD WEATHER LANDING TODAY — ITS PROBLEMS AND LIMITATIONS

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16. Abstract The limitations of ILS approach procedures are discussed for the various CAT landing conditions. Legal aspects and procedures for CAT I, II AND III conditions are briefly described. Deficiencies of existing systems for poor-weather conditions are elaborated and remedies suggested. Relationships between landing requirements, weather conditions and traffic flow and density are established.

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BAD WEATHER LANDING TODAY — ITS PROBLEMS AND LIMITATIONS

D. Brunner*

1. STATE OF THE ART /3**

Last winter we all experienced delays and cancellations of flights. These inconveniences were not due to strikes but were solely due to the weather, even today. Advances in the area of poor weather landing have still to be made. Nevertheless, a great deal of effort has been devoted to this within Europe. In comparison to the United States, almost all European airlines today carry out landings with minimum 100-foot $\hat{=}$ 30 m vertical visibility and 400 m horizontal visibility. In the entire world, the French domestic carrier has the minimum values of 50 ft $\hat{=}$ 15 m vertical visibility and 150 m horizontal visibility. In England, BEA is preparing for automatic landings according to operational stage III.

2. OPERATIONAL LIMITS

2.1. Categories

The minimum vertical and horizontal visibility values show that, at the present time, we are not yet completely independent of the weather. A minimum visibility must be provided for the aircraft to take off and land. Complete independence from

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meteorological visibility, i.e., all-weather landing is to be carried out in three stages.

Operational State I (CAT I) (generally achieved today) requires horizontal visibility of 800 m and vertical visibility of 60 m.

Operational State II (CAT II) (partially introduced today) /4 cuts the visibility of Stage I in half: 400 m horizontal visibility and 30 m vertical visibility.

Operational State III (CAT III) is divided into a to c and is not yet allowed for the airlines. IIIa requires 200 m horizontal visibility and *no* vertical visibility, IIIb requires enough horizontal visibility so that taxiing is possible on the ground, and IIIc finally is to allow operation without any visibility at all.

2.2. Minimum Requirements by Law

The operational stages define the point at which visual approach is continued. The closer this point is to the touchdown point, the less time will remain for correcting deviations from the guide beam. When the minimum visibility is decreased, the ILS system component requirements increase as well as the flying accuracy of the pilot and the flight controller. Increased requirements are placed on obstacles in the approach and takeoff sector of the airport.

An obstacle-free limit is specified for any runway, independent of existing ground obstacles. If the aircraft reaches the altitude of this obstacle clearance limit (OCL) without any ground visibility, then it is necessary to introduce procedures which make the plane pass over the runway and attempt the landing again. The OCL therefore is a function of:

- the selected approach method,
- the operational stage, and
- the local obstacles in the approach region

and is the altitude from which either the landing approach can /5
be carried out according to vision or, if there is no ground visibility, the aircraft reattempts the landing using instrument displays.

2.3. Operational Requirements for Airlines

The authorities define the operational states, specify the OCL, and require the airlines to specify so-called company minimas. These company minimas are specified in the form of horizontal and vertical visibility, depending on the flight properties and equipment on each type of aircraft, and starting with the OCL as an absolute minimum.

In addition to ILS landing approaches, sometimes so-called non-precision approaches are carried out, which are approaches with landing aids which are less accurate than the ILS. The ADF, VOR or the surveillance radar are used as nagivation systems. In such approaches, the horizontal visibility must be at least 1.5 km and the vertical visibility must be 400 feet. If we do not consider such non-precision approaches, it is necessary to take into account the following criteria when determining the operational limits of precision approaches:

1. Operational state for approach

It is determined by the onboard equipment of the approaching aircraft and the ground equipment of the airport.

2. Obstacle clearance limit of the selected runway

This altitude depends on whether the approach and restart sector are free of obstacles. It is the altitude specified by the authorities below which it is not permissible to fly without visual contact with the ground.

3. Weather minima of the airlines for each aircraft /6

The weather minima, company minima, specify the minimum horizontal and vertical visibilities at which approach can still be carried out, considering points 1 and 2 and the onboard equipment. This company minima also specifies by how much the minimum values must be increased for the following cases;

— partial failure of the ILS,

— crew with little experience.

3. PROBLEMS OF POOR WEATHER APPROACHES

3.1. Landing System

The instrument landing system available today is an approach aid rather than a landing aid. As already follows from this definition of CAT I and CAT II, visual references are required for landing itself. In the case of CAT III, it will be necessary to deviate somewhat from the "see to land" concept either entirely or in part. If we assume a standard runway width of 150 feet, we find the following permissible deviations (ICAO DOC 8636) from the tolerances of CAT II-ILS:

Refraction of the ILS guide beam	± 25 feet
Onboard receiver tolerance	± 39 feet
B707 with 5° drift angle	± 7 feet

(antenna in the fuselage forward section)	
One half track of a B707 main landing gear	13 feet
Total	± 84 feet

This means that, without any indicated deviations and without considering the polarization errors of the onboard antenna, it is possible for one of the main landing gears to be at the threshold outside of the taxiway. Conversely, if the total system has no errors, a deviation of 75 feet (1/2 of the taxiway width) at the threshold is only indicated at about 20% of the total deflection (1 Dot), so that the display sensitivity is quite low. In addition, the reception field strength is low because of the small elevation angle ($<0.2°$) referred to the localizer antenna. /7

In the case of glide path control, the glide path signal loses importance as the threshold is approached. Therefore, the refractions and onboard instrument tolerances do not have as much effect as for the localizer signal. On the other hand, the radar altitude measurement for CAT II approach is quite problematical in the case where there are terrain undulations or tide influences (special terrain profile maps).

The localizer and glide path ground displays are controlled by a monitor. As soon as the monitor detects that the CAT II tolerances have been exceeded, one switches to the backup transmitter. If the tolerances still exist after this switching has occurred, the glide path installation is turned off, or if the localizer fails, the entire installation is turned off. This often happens, because the monitor operates in the near field. Even small changes in the dielectric constant of the ground can produce this turning off. It was found that the near field perturbations which bring about the turnoff do not influence the far field as much, so that they would lie outside of the tolerances. It is also unsatisfactory that two localizers and glide path transmitters are available but that there are not two antenna installations as well.

It is not appropriate to monitor the approach using radar /8
above the CAT I minima because an aircraft with a span of more than 100 feet is such a large and diffuse target on a radar screen that it is no longer possible to actually determine the true deviation.

3.2. Visual Impression of Pilot for CAT II

As soon as the aircraft has ground visibility in the case of CAT II, a rapid decision must be made based on prevailing visual impressions of whether a landing is possible or not. At this time, the landing trajectory threshold is not yet visible and therefore, the usual target point available to the pilot under good visual conditions is not available. This point is located in the vicinity of the touchdown point, about 300 m in front of the threshold. During the approach phase, very often the so-called "duck under maneuver" is used, in which the glide path is underflown. This maneuver is produced by an unconscious reaction of the pilot. He identifies the relative position of the natural horizon with respect to the aircraft with the limiting line of the visible terrain. By applying pressure, he moves this limiting line to the point on the wind screen at which the natural horizon is located under good visual conditions.

Because of this behavior, shortly after CAT II was introduced, several accidents occurred, so that during the final approach, there were excessive descent velocities which could not be explained. Nevertheless, the experienced CAT II pilot will consciously fly such a reduced "duck under maneuver," so as to emerge as fast as possible from the region where there is oblique vision and to enter the range where there is better horizontal vision and where he can again obtain his usual target point. A landing with an advanced target point is much more difficult to fly because of the unfavorable perspective conditions (Figure 1).

An additional difficulty in the case of CAT II approach is /9 the fact that, during flareout, it is necessary to carry out directional and descent velocity corrections, which are already concluded in the case of CAT I approaches.

3.3. CAT III Landing

In the case of CAT II approaches, a great degree of skill is required by the pilot in order to equalize possible deviations in a very short time. Automatic systems will perform this task in the case of CAT III. The pilot becomes a manager of his systems who decides whether another approach should be made or whether the landing should be carried out. In order to successfully introduce CAT III, the automatic landing systems must be completely reliable and it is also important that the pilot has the information necessary to perform the "go" — "no go" decision. The reliability and type of display of this information will greatly influence the trust the pilot has in the automatic system. In the United States, at the present time, special onboard radar devices are being tested which give a real picture of the cloudy runways and represent independent surveillance units.

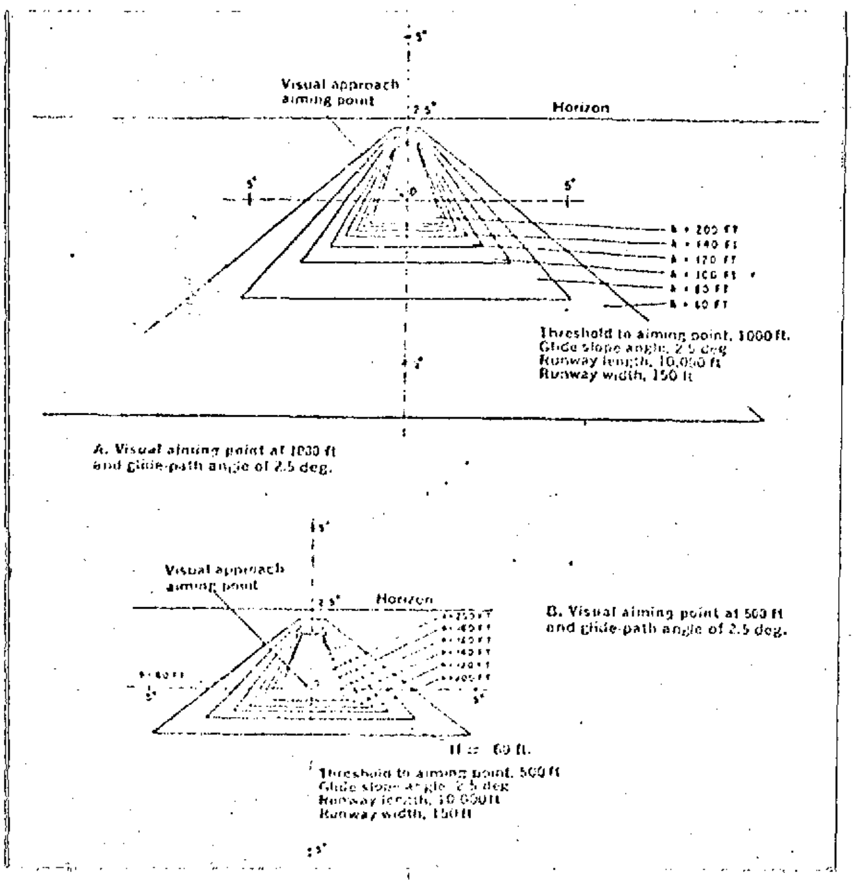

Figure 1. Dependence of the landing path perspective on the target point (from G. B. Leichford, the 100-foot barrier), Astronautics and Aeronautics, 1964.

3.4. Interaction Between Poor Weather and Traffic Flow

In the case of poor weather landings, there is a type of chain reaction between false approaches and the aircraft waiting on the ground: the more aircraft are waiting on the ground, the greater will be the refractions of the ILS, which again increases the number of false approaches.

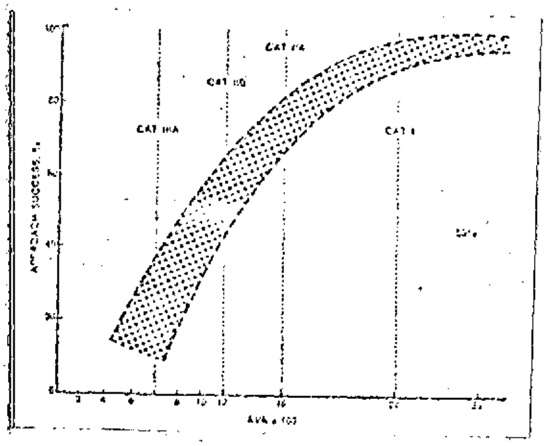

Figure 2.

Figure 2 is taken from the publication of the AWOP III meetings of 1969 and clarifies this fact. It is interesting that the experiences of Air Inter give an optimistic picture: only four false approaches occurred out of 134 approaches during the first year, which corresponds to a success rate of 97%. The success rate is similar for the CAT II approaches of European airlines. /10

This success rate says nothing about the considerable delays caused by poor weather airline traffic. As soon as the visibilities approach those of CAT II, the traffic flow will be considerably disturbed by the following factors:

— simultaneous landings on parallel runways (distance smaller than 6,000 feet) are no longer possible;

— simultaneous takeoffs for CAT II landing approaches cannot be carried out;

— by holding open the sterile CAT II areas, the traffic flowing to the takeoff runway is disturbed;

— the false approaches and the aircraft in holding patterns make the traffic more dense in the short distance sector, until the saturation limit is reached.

On the other hand, if good visual flight conditions prevail, /11
it is always fascinating to observe the flexibility and capacity reserve in the use of takeoff and landing runways. It is also remarkable how a jumbo jet can be directed from one runway to another. This clearly shows how much better the pilot can

process optical-visual information than electronic-displayed information.

4. SUMMARY AND FUTURE

4.1. The ILS

Most problems of poor weather landing are the result of the fact that the ILS is not a landing system but an approach aid. Its imperfections must be compensated for by additional installations such as radio altitude measurements, optical landing aids, etc. This compromises the total capacity of airline traffic.

4.2. System Surveillance and Landing Decision

The decision of the pilot whether a CAT II or III approach is to be continued or to be terminated in the final analysis is based on visual impressions containing more or less information. The fate of over 300 persons depends on this decision which has to be made in a very short time.

Research should be conducted more on the support of the pilot in making his decision. The flight safety and capacity of airline traffic is increased to the extent that the pilot has available information comparable to that which he has under good flying conditions. In spite of the technical advances, it /12
is very difficult to display such information using technical means. Therefore, it is logical and very interesting to artificially improve optical vision. France is the leader in this area at the present time. The Turboclair method uses gas turbines which blow hot gases over the takeoff runway. The

fog drops are evaporated because of the heat and the kinetic energy. The firm Linde in Germany is presently testing artificial vision improvement. The principle corresponds to a heat pump.

4.3. Future

In addition to improvement of the landing systems, much work still remains to be done to provide the pilot the necessary aids for poor weather landing. There are promising new areas which German research and industry associations should tackle.

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